DESIGN GUIDELINES FOR SAFETY OF IN-VEHICLE INFORMATION SYSTEMS

by

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These Guidelines contain advice on the design of in-vehicle information systems. They are for guidance only, and do not purport to be full or accurate statement of law.

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1 INTRODUCTION

1.1 BACKGROUND

A wide variety of in-vehicle information systems (IVIS) currently exist and many more will become available in the near future. These systems aim to help the driver by providing information, for example, about routes, traffic congestion and accidents. Because these systems can provide drivers with real-time information (and are becoming increasingly sophisticated; and thus more useful) there is a growing concern that they may interfere with the primary driving task and thus compromise safety.

Similarly, the possibility of providing drivers with an in-vehicle office environment (with telephone, fax machine, e-mail and computer) raises serious safety concerns - as do some advanced entertainment systems. While these systems should come with 'advice' about not using them while driving (as is currently the case with mobile phones) the driver may be tempted to ignore such advice. In addition to the distraction issue, there are also potential safety problems with respect to the driver being given incorrect information by the IVIS (for example, advising them to drive the wrong way down a one-way street). It is thus essential that drivers be reminded about their responsibilities regardless of information provided by these systems.

The guidelines in this document are intended to alert designers (and manufacturers) of IVIS to some legal and ergonomic issues relevant to safety. Since there are already a sizeable number of relevant guidelines, standards and codes of practice in existence (see Technical References in section 9), the objective of the guidelines in this document is to produce a 'user friendly' synthesis of current knowledge, and provide up to date guidance on where to locate more detailed information.

These guidelines can be viewed as a companion document to the 'IVIS HMI Safety Checklist' that was developed in order to assess safety issues raised by existing or planned IVIS systems (Stevens *et al*, 1999). It is likely that if the advice provided in these guidelines is followed, any resulting system is more likely to be assessed favourably based on an evaluation by this (or an equivalent) Checklist. In addition to issues raised by the Checklist, these guidelines include a discussion of some legal issues raised by IVIS (see section 8). The manufacturers' responsibility with respect to system design or failure (and indeed the status given to guidelines, checklists and compliance assessment methods) is becoming increasingly important and complex.

While this document aims to present objective and measurable solutions to many design concerns, there is likely to remain some element of subjectivity; for example, as to what is and is not acceptable in terms of whether IVIS will create problems for drivers rather than help them. Ideally, systems should be designed taking account of safety issues at all stages. However, many new systems are likely to pose unique challenges for designers in achieving an optimal human-machine interface; and IVIS designers may have problems in discovering what up-to-date guidance is available, and where it can be found. These guidelines aim to assist with these issues.

1.2 SCOPE AND OBJECTIVES

These design guidelines are based on current understanding of ergonomic good practice and cover the many issues that need to be considered when designing and evaluating in-vehicle information systems. They put safety and usability as a paramount design concern.

The objective of these guidelines is to provide designers and manufacturers (and others within the supply chain) with a summary review of the factors that need to be considered in the design process of IVIS, in an easy to use format. They are not intended as an encyclopaedic collection of all that has been written, or is known, on the subject. The policy adopted was to provide sufficient information such that – in most cases – further references would not be required. However, where necessary appropriate references are provided to supplement the information and advice.

The guidelines primarily deal with systems that provide the driver with information specific to his journey such as congestion, incident (eg accident) warnings or route guidance information. Although they are not intended for designers of in-vehicle entertainment systems (such as radios, cassette and CD players) or mobile telephones (whether hands-free or otherwise), many of the issues raised (eg driver 'distraction') will be similar and the principles behind the guidelines will thus be largely transferable. Similarly they are not intended to deal with advanced driver assistance systems (ADAS) that aim to assist drivers with vehicle control, such as speed setting, following at a safe distance and lane keeping.

The guidelines are primarily aimed at systems designed for 'private' car drivers, rather than those used in fleet management systems which can, for example, monitor driver activity and provide drivers with work related instructions or performance feedback. The guidelines will of course be largely transferable and applicable to systems used by individuals in the course of their work, for example by drivers of fleet cars, HGVs, PSVs and ambulances. These drivers may equally be required to enter system passwords and receive task information by means of visual displays. However additional issues concerning, for example, employer and employee responsibilities are covered only very briefly within this document (see section 8.7).

There are various sources of information relevant to the design of IVIS (see section 9). For example, the BSI Code of Practice (BSI-DD235, 1996) sets out to provide recommendations to assist designers, manufacturers, suppliers and installers regarding safety-related issues affecting systems used by drivers in-transit. It overviews key human factors design considerations, eg control and display location, training, system interaction, etc. It provides both normative data and references to supporting text. The present document can be seen as providing an updated version of the BSI Code of Practice that takes account of recent developments in the area.

1.3 HOW TO USE THE GUIDELINES

The guidelines are intended to be a first-reference document that can be used at each stage of the design process. In some cases critical issues will arise at the initial conception stage depending on the system being considered. Ideally assessment should be a continuous part of the entire design and development process. The

guidelines provide both normative data and an extensive list of further useful reference documents.

If there are queries about the ergonomic information provided in these guidelines initial reference should be made to the named authors at TRL Ltd. If the query relates to the current status of the guidelines with respect to its legal status within UK and/or EU queries should be addressed to Transport Technology and Telematics Division of the UK's Department of Transport, Local Government and the Regions (DTLR). TRL Ltd, and DTLR, accept no responsibility for the currency or comprehensiveness of the materials contained within these guidelines. Although great care has been taken in the compilation and preparation of these guidelines to ensure accuracy, TRL Ltd cannot in any circumstances accept responsibility for any errors or omissions.

1.4 FORMAT OF DOCUMENT

This document provides a systematic review of the many factors that need to be considered in the design process of IVIS systems.

Section 2 describes the different stages of the design process and considers briefly what each stage entails and the possible need for conducting assessments at the different stages.

Section 3 deals with the documentation and user instructions that may need to be provided with the system.

Section 4 provides guidelines (if required) about how the IVIS should be fitted within the vehicle.

Section 5 covers ergonomic issues of how the driver interacts with the system with respect to controls, visual displays and the use of auditory information.

Section 6 discusses more complex interface – or 'dialogue' – issues.

Section 7 considers more general safety related aspects of IVIS, such as the need to provide the driver with accurate and timely information.

Section 8 considers the legal situation and issues of liability and responsibility.

Sections 9 and 10 provide 'References' and a 'Bibliography' respectively. The Bibliography includes references that are interesting 'further reading', but are not specifically referred to within these guidelines.

A list of 'Abbreviations' and a 'Glossary of Terms' are given in section 11.

2 SYSTEM DESIGN AND ASSESSMENT

2.1 SYSTEM DESIGN

2.1.1 General

Figure 1 shows one representation of the main stages in the system design process.

Before a system can be designed, there must be a reason for it to exist; the objectives of a system (considered in Stage 1) are normally formulated in very general terms (eg navigate the driver to destination). The performance specifications describe what the system needs to do to meet its objectives (eg transmitting both visual and auditory information). These should reflect the context in which the system will be used and the skills available among the users. The IVIS also needs to be compatible with the primary driving task (ISO/DIS 17287, 2000). Stage 2 defines what functions need to be performed to meet the objectives and performance specifications formulated in Stage 1 (eg select destination, select route, provide directions, etc). In Stage 3 the basic design is defined. After this, more attention can be given to the human-machine interface in Stage 4. In Stage 5 attention is given to the documentation and training that is needed for the end user. Testing and assessment (Stage 6) is typically considered after this stage, but ideally should be carried out throughout the whole design process.

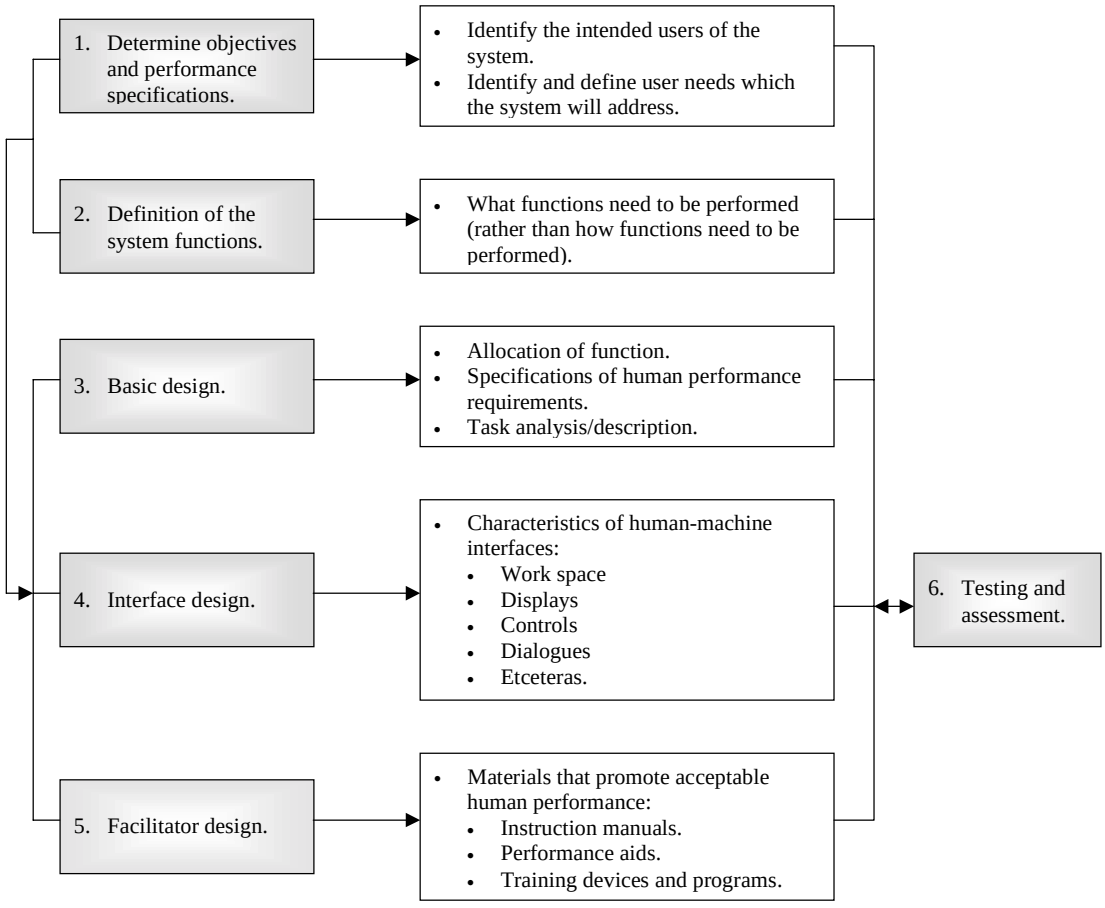
1. Determine objectives and performance specifications.
Identify the intended users of the system.
Identify and define user needs which the system will address.
2. Definition of the system functions.
What functions need to be performed (rather than how functions need to be performed).
3. Basic design.
Allocation of function.
Specifications of human performance requirements.
Task analysis/description.
4. Interface design.
Characteristics of human-machine interfaces:
Work space
Displays
Controls
Dialogues
Etceteras.
5. Facilitator design.
Materials that promote acceptable human performance:
Instruction manuals.
Performance aids.
Training devices and programs.
6. Testing and assessment.

Figure 1: Stages in design process (adapted from Sanders and McCormick, 1992)

Information about the system, user characteristics and how the system will be used should be established early in the design process - and used to facilitate both the design and assessment process. These principles are equally important where new functionality is being added to existing functionality, to ensure that HMI issues are considered for the overall integration of new and old. Human factors professionals should be involved throughout the design process.

2.1.2 System requirements

Detailed design issues that need to be considered vary with the type of system or systems being developed and their functionality.

At a very early stage of the design process a number of questions should be asked. For instance:

- What do drivers need systems to do?
- What functionality must be provided by the system to meet these needs?
- By what means did drivers address their needs prior to availability of the system (eg use maps, listen to radio)?
- What are the likely conflicts between system use and normal/safe operation of the vehicle?
- What functionality must be provided by the system to avoid misuse by the driver?

2.1.3 System users

Information about which drivers the system is intended to help needs to be taken into account in the design process and the system should ideally be designed with all users in mind, whether male, female, young, old, able bodied or disabled. While some systems are intended for all drivers, some will target particular groups. The type of user may be characterised by driver demographics such as their sex and age or by the reason for the trip. For example, holiday drivers might want to receive different information to high mileage business drivers.

It is important to appreciate that drivers differ markedly in their physical, perceptual and cognitive abilities and systems need to be designed with this in mind. Where appropriate, these guidelines give special considerations to other user groups that have distinct needs (eg the elderly). In addition, attitudes and emotional state will vary between drivers and these may critically influence their behaviour.

Drivers do not perform consistently while driving; they experience lapses of concentration, suffer from fatigue and stress (whether social, work or journey related) - and sometimes consume alcohol. In contrast, drivers or developers undertaking an on-road assessment of a new system may be highly motivated and focussed and consequently unrepresentative of the wider user group. It should also be recognised that driver behaviour during initial use (eg during testing and assessment) may be very different from that adopted after the driver has habitually used the system for a number of months.

2.1.4 Road and traffic conditions

The designer should recognise that the system will not always be used in the conditions for which it was originally designed and that conditions can vary markedly. Assessment should therefore involve a wide range of road and traffic conditions.

2.1.5 Environmental conditions

Designers need to consider the range of environmental conditions in which their systems are likely to be used. These should include darkness, bright sunlight, heavy rain or fog, etc. Driving at night changes the driving task and IVIS design issues considerably. Different lighting conditions also demand specific design features, for example an anti-glare screen to compensate for bright sunlight.

2.2 SYSTEM ASSESSMENT

2.2.1 Importance of assessment

Designers should recognise that system assessment is important at all stages of design, both for improved product development and to reduce potential liability problems in the future. A formal assessment methodology or procedure should ideally be applied to ensure a continuous and consistent assessment schedule.

It is advisable that user assessments (ideally with inexperienced users) are conducted at an early stage in order to highlight unexpected circumstances of system use and misuse. Even if an IVIS is created with careful adherence to design guidelines and with consideration of user needs, it is advisable to conduct final usability trials using both ‘naïve’ drivers as well as ‘experts’ who might have experience of similar systems. Approaches to conducting assessments of safety and usability of IVIS are described in sections 2.2.2 – 2.2.4.

If a new design is based on an existing system and is intended for use in the same circumstances and by a similar group of drivers, then a limited assessment by independent experts *may* be sufficient.

2.2.2 When to assess?

If the system uses elements that have not been tested in vehicles before, it is advisable to assess the system's safety and usability early in the design process and again when a prototype system is available.

In all cases it is advisable to plan and undertake assessment trials throughout the design process. Tests should be conducted as soon as the first prototype systems are available. Final tests must also be done to ensure the systems are safe for use while driving. In some circumstances it may be possible to test pre-prototypes using mathematical or structural models, mock-ups and simulated driving techniques.

2.2.3 Who should be involved?

Designers should involve suitably qualified and experienced ergonomic/human factor personnel at all stages of any assessment conducted, either utilising appropriate internal resources or engaging the services of external consultants where necessary. Potential IVIS 'end users' should also be involved. The amount of training and/or experience that these drivers have with the system will depend on what exactly is being tested. If it is the comprehension of the system instructions provided that are being assessed, then the users should be inexperienced. However, if the trials demand driving in busy traffic then a certain amount of familiarity with the system would be advisable.

Both male and female drivers, the young and elderly should participate. The required number of drivers participating in the evaluation depends on the salience of problems being investigated and their probability of occurrence (Lewis, 1994). It is unlikely that a system evaluation would be effective using anything less than 10-12 end users (Nielsen, 1993).

2.2.4 Assessment method and criteria

There are a number of general methods of IVIS assessment. One method considers the ergonomic requirements of the specific IVIS design. A second method assesses the IVIS 'in-situ' (but not necessarily on the road) according to human and system performance criteria. Other methods can involve the use of focus groups, mathematical models and user trials. The most appropriate method to use will depend on when in the design process it is being applied and what aspect of the system is being considered.

The first method is essentially a test of how well the system meets a set of design guidelines, which may be performance criteria set by the producer. It may be based on such requirements as the anthropometric and ergonomic standards for physical sizing, locations of controls, and the labelling and display of information (see section 5) and is usually conducted by human factors experts against some pre-specified objective criteria. There are different systematic approaches to these expert evaluations such as the TRL/DETR IVIS Checklist (Stevens *et al*., 1999) and the Heuristic Evaluations method (Nielsen, 1993), both of which have been found to be effective for evaluating IVIS. Both of these methods can identify key usability and safety issues. They give problems a severity rating to guide re-engineering priorities and provide solutions rather than just a critique. Both of these expert methods can be used very early in the development phase and can be task-based or holistic.

A second method evaluates the system more quantitatively with respect to driver and system performance. Although there is no single indicator for acceptable usability or safety performance this method will need to take account of issues such as reliability, validity and sensitivity (ISO/DIS 17287, 2000).

Reliability can be indicated for example, by two types of system error; errors of omission where a stimulus is not detected, when the 'hit' rate for stimulus detection should be high, and errors where a response occurs when no stimulus is present (false alarms), when the false alarm rate should be low. Some examples of reliable and validated measures are provided in Table 1 (on page 13).

Designers need to recognise that system assessment should never jeopardise the safety of the participants (subjects), the evaluator or the general public. With this aim desktop, laboratory or driving simulator assessments may be used to conduct preliminary assessments and to identify more serious safety and usability concerns before conducting trials in real road situations. In some cases it may be judged worth conducting initial trials on a test track.

Ideally final safety assessment should be performed during road tests. It is also necessary to tailor any assessment with respect to the existing situation or 'base case'. For example, if the IVIS provides route guidance it is necessary to consider whether its use should be compared with traditional route finding techniques (with information provided by road signs; and with or without the use of a conventional map - that might be held or placed on the passenger seat). In this case test drives could be undertaken, for example in an unfamiliar location, and compare performance of the IVIS in relation to other in-vehicle tasks (eg tuning a radio). Note should be made of all the difficulties encountered by drivers during these assessments.

There is also the complex issue of how to assess the balance between an IVIS that can provide regular (possibly 'small') benefits over a long period of time, but may very infrequently result in a single 'extreme' negative outcome. For example failing to warn a driver about severe congestion on the route ahead, or instructing the driver to make an illegal manoeuvre at a junction. This question is likely to depend critically on the consequences (and/or frequency) of the system 'failure', although accurately identifying such infrequent events during assessment trials conducted over a limited period of time may prove very difficult.

Any significant degradation in performance when driving with the IVIS should be a concern and if any basic safety related tasks are compromised the decision should be taken to restrict their use to when the vehicle is stationary.

Table 1: Measures of IVIS Safety and Usability Performance

<table>
<tr><th>System Performance</th><th>Driver and Vehicle Performance</th></tr>
<tr><td rowspan="2">Efficiency
▪ Number of button presses.
▪ Number of errors.
▪ Task success rate.
▪ Task completion time (eg the '15 second rule', Green, 1999).

Driver workload
▪ Subjective rating/attitudes (eg usability and usefulness ratings).
▪ Psychophysiological measures, (eg heart rate and heart rate variability).
▪ Secondary task performance.</td><td>Driver
▪ Eye movement behaviour (eg mean and maximum glance duration, glance frequency, eyes off road time; Wierwille, 1993).
▪ Situation awareness (Endsleigh, 1995a; 1995b).
▪ Reaction time to events (eg peripheral detection task; Olsson and Burns, 2000).</td></tr>
<tr><td>Vehicle
▪ Lane position variance (Tijerina et al 1995; Tijerina et al, 1998).
▪ Unplanned lane departures.
▪ Steering reversals.
▪ Steering and speed entropy (ie unpredictable patterns).
▪ Mean speed, speed variance.
▪ Minimum headway and headway variance.
▪ Minimum time to collision.
▪ Number of critical incidents and crashes, speed on impact.</td></tr>
</table>

3 SYSTEM DOCUMENTATION AND USER INSTRUCTIONS

3.1 GENERAL

Designers should consider the advantages of providing systems where the need for complicated instructions or training is minimal. The design process should recognise the need to provide instructions, written or otherwise, for how the system can be used – and (importantly) how it should be used without compromising safety. These should be assessed (eg for comprehension) and cover all relevant aspects of installation, operation and maintenance. Designers need to ensure that they play an active role in the production of any manuals and documentation produced for end users.

Any instructions provided should be durable (European Statement of Principles, 1998) and contain the advice that they should be retained within the vehicle so that future owners will be able to learn about the safe operation of the system. Instructions should also inform drivers not to use the system until they are content that they have (ideally) received sufficient instruction to do so safely or have at least had the opportunity to familiarise themselves sufficiently with the system.

3.2 COMPLIANCE WITH REGULATIONS, STANDARDS AND RECOMMENDATIONS

Standards and guidelines have been developed to assist designers and manufacturers in producing usable products that meet the minimum safety requirements. Documentation should therefore be developed and retained to provide evidence of compliance with regulations, standards and recommendations and the consideration of human-machine-interface (HMI) issues.

Regulations frequently relate to safe system use and crashworthiness in the event of an accident. Thus, designers need to consider the safety of vehicle occupants and how they can be protected from injury caused by the IVIS in the event of an accident.

3.3 PACKAGING INFORMATION AND INSTRUCTIONS

Designers and manufacturers of IVIS, whether ‘factory-fitted’ or ‘off-the-shelf’, must not misrepresent what a system can do or how it should be used in a way that might encourage unsafe use. This applies to both what the consumer is told at the point of sale, and any publicity or other sales materials that are displayed or produced (EC Code on Advertising, 1995).

Designers and suppliers should therefore ensure that the packaging accurately conveys system functionality, and makes the user aware of system capabilities and limitations. It should not encourage unsafe or illegal use nor create unrealistic expectations on the part of the potential users; it should promote road safety and compliance with existing traffic regulations, and recommendations for road and vehicle use.

System instructions should be provided in the users native language, or a form designed to be understood by the driver.

The instructions should:

- be correct, simple and clear, relevant, well defined, and presented in a logical order
- clearly state which aspects of the system are intended for use by the driver when driving, and those aspects that are not intended for use by the driver when driving
- identify the intended user groups, if specific skills or capabilities are required or if the product is unsuitable for use by particular users
- include actions required in the event of a system failure and a trouble shooting (or help) section to easily locate specific information
- state clearly that the driver retains absolute responsibility for the safe operation of the vehicle and compliance with current traffic regulations, regardless of any information provided by the IVIS
- provide a statement of compliance with other systems.

Manufacturers should make the assumption that if they do not either directly stipulate that a particular function should NOT be used while driving, or physically disable a function when the vehicle is moving, then drivers are likely to assume it can be used on the move.

In order to ensure the continued safe operation of the IVIS, and to ensure the drivers are aware of their responsibilities, the user manual should outline the maintenance requirements of the IVIS, including the frequency at which software should be updated.

3.4 TRAINING

Designers should consider the advantages to be gained by integrating operating instructions within the system – or even providing a programmed tutorial as part of the system; although this will not always be appropriate or possible.

The possibility of providing a ‘hands on’ element to any training should also be considered, either in the form of simulated use or an accompanied trial drive; again this may not always be a realistic option.

4 SYSTEM INSTALLATION

4.1 DESIGNER/MANUFACTURER'S INSTRUCTIONS

Manufacturers and designers of IVIS intended for fitting into vehicles need to provide clear instructions for the location and installation of the IVIS. These instructions should be tested for comprehension on a group of end users. They should also take adequate steps to ensure that those doing the installation are aware that any IVIS should:

- be located and fitted in accordance with the relevant regulations, standards and manufacturers instructions for installing equipment in vehicles (UK Code of Practice 2.1.1, EC Directive 74/60/EEC)
- not be freestanding within the vehicle. Note that the EC European Statement of Principles: Expansion HMI TF, 1998, does permit some devices (eg automatic garage door openers) to be free-standing – but such devices do not fit into the definition of IVIS employed here)
- be easily usable from the driver's preferred seating position
- be fixed securely such that it is free from vibration
- provide information on system compliance with any standards and regulations.

Designers also need to be aware that:

- if the front seat passengers as well as the driver are likely to use the system their use should not interfere with the driver in any way
- IVIS need to be designed and installed in order to be crashworthy and to minimise injury potential in the event of an accident.

4.2 PHYSICAL AND VISUAL ACCESS TO DRIVER CONTROLS AND DISPLAYS

Compliance with recommended control and display locations should ensure that the driver's ability to maintain full and safe control of the vehicle is not affected by installation of the IVIS (BSI DD235, 1996). The system should be installed such that:

- it does not obstruct or interfere with existing controls or displays required for the primary driving task from the driver's normal seating position
- it does not obscure the driver's view of the road scene through the windscreen, side windows or rear view (EEC/71/127, EEC/77/649)
- if the physical position of the system can be altered/adjusted so that it does obscure the driver's view, the manufacturer's instructions should clearly state the intended position for use while driving.

4.3 COMPATIBILITY WITH OTHER SYSTEMS

Designers need to recognise that more than one IVIS system may be used in the same vehicle. They need to be aware of, and consider the safety issues relating to physical or electronic interference between systems and ensure that where systems are

integrated with a shared display, the system that is currently operational is clearly identifiable by the driver.

Where a visual display is to be shared between different systems, conflicts between the systems should not occur. In the event of a conflict arising the system should prioritise and present any time critical information first. Similarly there should be no conflicting auditory outputs from different systems or conflict between visual and auditory messages.

5 DRIVER-SYSTEM INTERFACE: INPUT CONTROLS, VISUAL DISPLAYS AND AUDITORY INFORMATION

5.1 INPUT CONTROLS

The primary function of a control is to transmit information (Sanders and McCormick, 1992). The system controls should be designed so that they are easy for the driver to use without adverse impact on the 'primary driving task' (see section 7.2.2). Adverse impact on the driving task occurs when badly designed controls induce negative consequences on the ability to drive safely (Stevens *et al*, 1999).

In-vehicle controls should be designed for the intended user group. This requires a clear decision as to who the user group is, together with compatible instructions and publicity to support this decision. The user group may include disabled users, as well as older (and weaker) drivers. Thus controls should be usable in all situations and conditions that are likely to occur (eg in darkness, while wearing gloves). It is therefore advisable that they be tested in such contexts. Safety critical design decisions should be documented and reflected in user manuals.

Complex operations that require the use of both hands, or long un-interruptable sequences of interactions (eg more than 5 keystrokes) should be disabled whilst the vehicle is in motion (SAE 2364).

5.1.1 Location

Controls should be easy to reach from the normal driving position and should not obstruct access to other driver controls or displays. They should not encroach upon or interfere with normal leg, hand and arm movements, in order to avoid accidental activation.

5.1.2 Layout

Each control should:

- Be usable without inadvertently activating another control.
- Be located in close proximity to their associated display.
- Be located so that the driver’s hand does not block his view of an associated display.
- Move in a direction that is consistent with the display.

High priority controls should be easiest to reach and operate. The plane of the displays and controls should be perpendicular to the driver’s line of sight.

The centres of controls that need to be operated *non-visually* should be positioned at least 15 cm apart (Defence Standard 00-25 Part 10, 1992).

5.1.3 Design

The design of all controls used should be suitable for their function (see Table 2), and thus the type of control will depend on the sort of information to be transmitted. Controls that require fine control or adjustment (for example a stylus) or large forces are unsuitable for in-vehicle systems that are used while driving, as are controls that are designed for language or data entry such as keyboards.

Table 2: Selecting discrete controls (Adams, 2001)

Type	**Use**
1. Linear	
Push button	For brief 'one touch' activation of a function.
Slide	Where two or more positions are required along a continuum to allow easy recognition of relative switch settings (eg auditory levels across channels).
Toggle	Where two positions (typically on/off, left/right) are required or when space is severely restricted.
Rocker	Where two positions are required and toggles may cause snagging problems or where limited panel space makes separate labelling of switch positions not possible.
Push-pull	Where two positions are required and such configuration is expected or where panel space is scarce and related functions can be combined (eg ON-OFF/volume control). Three-position push-pulls should only be used where inadvertent positioning is not critical.
2. Rotary	
Selector	Where three or more positions are required. In two-position applications where swift visual identification is more important than positioning speed.
Key operator	In two-position applications to prevent unauthorised operation.
Thumb-wheel	Where a compact digital control-input device with readout is required.

5.1.4 Discernibility

Designers should ensure that controls are easily discernible during daylight and darkness. They should use different methods to aid recognition such as using colours, shapes, sizes, locations, textures, and (possibly) sounds. The advantages and disadvantages of the different methods are set out in Table 3.

When different size controls are used to aid discernibility, these should be limited to a maximum of three distinct sizes within one functional area.

Table 3: Advantages and disadvantages of different discernibility methods (Adams, 2001)

	Type of coding					
1. Advantages	**Location**	**Shape**	**Size**	**Mode of operation**	**Labelling**	**Colour**
Improves visual identification	✓	✓	✓		✓	✓
Improves non-visual identification (tactile)	✓	✓	✓	✓		
Helps standardisation	✓	✓	✓	✓	✓	✓
Aids identification under low levels of illumination and coloured lighting	✓	✓	✓	✓	when illuminated	when illuminated
May aid in identifying control position (settings)		✓		✓	✓	
Requires little (if any) training: is not subject to forgetting					✓	
2. Disadvantages						
May require extra space	✓	✓	✓	✓	✓	
Affects manipulation of the control (ease of use)	✓	✓	✓	✓		
Limited number of available coding categories	✓	✓	✓	✓		✓
May be less effective if operator wears gloves		✓	✓	✓		
Controls must be viewed (ie must be within visual areas and with adequate illumination present)					✓	✓

Controls should be separated by distances that are sufficient to avoid two buttons being pressed inadvertently. It should be recognised that drivers may have different manual dexterity, on occasions may not be able to devote total concentration and may sometimes be wearing gloves. In order to avoid confusion between positions there should be more than 2.5 cm between button centres (but also see section 5.1.2). For size coding to be effective, controls must be sufficiently different in size to make them different from each other (see Table 4).

Table 4: Minimum dimensions for finger operated controls (MIL STD-1472F, 1999).

Type	**Operating force**	**Dimension**	**Contact surface area**	**Clearance (centre to centre)**	
				Gloved hand	**Bare hand**
Push-button	1 to 8 N	8 mm	80 mm^2	25 mm	15 mm

5.1.5 Control input stereotypes

Controls should be designed in conjunction with conventional stereotypes. For example, turning a control clockwise is normally associated with ‘up’, ‘right’, or ‘increase’, while counter-clockwise is associated with ‘down’, ‘left’, or ‘decrease’. Under highly stressful or high workload situations, people often refer back to learnt

stereotypes, and if what they perceive does not meet their expectations, they are more likely to make mistakes.

5.1.6 Colour

Colour should be used effectively to aid the layout of controls. The meaning of the colour coding should be clear and should conform to stereotypical norms, for example red for alarm and amber for warning. Red/green and blue/yellow combinations should be avoided since these colour combinations might be confusing for people who are colour blind. The use of too many colours should also be avoided, a maximum of five different easy to distinguish colours is recommended (BS 5378 Part 1, 1980). Colours should be used consistently throughout the system. Colours should have the same meaning on all the screens that the system can use.

It should be noted that when using colour visual displays colour after effects can occur (such as the McCullogh effect which causes “pink snow” if green text has previously been read). ‘Floating’ of display elements can also occur with high colour saturation, thus colour must be used with care and with due consideration to changes caused by variations in luminance and contrast.

5.1.7 Lighting

The lighting of the controls should be adequate to identify the required control but should not distract the driver. Drivers should be able to adjust the level of lighting.

5.1.8 Feedback

Control operational feedback should be adequate, appropriate and timely. Operational feedback is adequate if it is obvious to the driver that a change has occurred in the system and that this change is a consequence of the input. A timely response should usually be given within 250ms (European Commission, 1998).

The user should be able to hear or see immediately if they have made an input error or incompatible choice.

The system should provide error messages in plain language and indicate the precise problem. It is even more important for the system to inform the driver accurately about any malfunction of the system.

Examples include when an address is entered that does not exist, the error message should say 'address does not exist', rather than 'error input'. When the sensor calibration data is lost, the system should inform the driver that accuracy of the route guidance system is reduced.

There can be safety implications when there is a difference between the actual function of a system and the driver's expectations based on previous information and experience. Therefore it is important for the system to make it clear to drivers when there is a change in status or a malfunction which modifies the system's performance, so that drivers can modify their behaviour accordingly.

5.1.9 Touch-screen controls

Current generations of touch-screens are not appropriate for use when mobile since they provide no tactile feedback concerning control orientation, location, separation from one another, or function, and consequently cannot be accurately operated 'eyes off'. Interaction with touch-screens often demand long glance duration, and consequently a high degree of visual resource allocation in order to locate and activate the control button; this type of interaction is not conducive to safe performance of the driving task.

If touch-screens are used in vehicles, they should be simple to use and suitable for the function they serve, the controls (unless extremely simple, such as on-off) should not work by ‘proximity’ but require light positive pressure for activation and provide auditory control activation feedback. Screens activated by proximity detection make it easy to inadvertently activate the wrong control; unless the responsive areas are very large.

5.1.10 Voice operated controls

Designers should note that speech recognition systems may not yet be sufficiently advanced to implement reliably in vehicles (Khalid and Helander, 2001). Those currently in use tend to have limited vocabularies and are not robust enough to provide high recognition accuracy, leading to frequent misinterpretations. Additionally, vehicle and passenger noise often interfere with the voice recognition system, while changes in people's voices due to fatigue and stress can make valid commands unrecognisable (Sanders and McCormack, 1993).

When using speech recognition systems:

- the vocabulary used should be familiar to drivers and should avoid using similar sounding words or phrases
- the system should give immediate feedback (ie within <250 ms) to the driver in regards to the recognition results
- the systems recognition accuracy should be high, particularly in safety critical situations (eg recognition 98% for hit rates and less than 5% false alarm rates)
- the system must be able to cope with expected amounts of background noise.

5.2 VISUAL DISPLAYS

5.2.1 General

Designers should note that visual information presentation is the most appropriate modality to use when information is complex, does not require immediate action, may need to be referred to again and/or is presented continuously (Sanders and McCormick, 1993). When possible and appropriate the use of both visual and auditory information presentation should be used.

Visual information presented on the IVIS should appear legible, accurate and be presented at the appropriate time. The size of the display images should be appropriate to their function. High priority visual information requiring immediate

action should be more prominently displayed and should be accompanied by an alerting auditory tone (Campbell *et al.*, 1998).

5.2.2 Location

For a driver to be in full control of the vehicle and aware of the dynamic road scene, there is a broad consensus that, apart from brief glances at mirrors or instrumentation, the driver's gaze should be directed towards the road scene. Visual displays positioned close to the driver's normal line of sight reduce the total eyes-off-the-road time relative to those that are positioned further away. Such positioning also maximises the possibility for a driver to use peripheral vision to monitor the road scene for major developments while principally looking at the display.

The higher priority the information has, the closer it should be located to the normal line of sight. The driver's normal line of sight refers to the direction of the driver's gaze out of the front windscreen onto the road ahead. Visual displays showing high priority information during driving should be located within 15° of the driver's vertical viewing position and ideally 15° horizontally (HARDIE, 1996) with a maximum separation of 30°.

Priority should be based on the display's relevance to driving, criticality, urgency and frequency of use. This may require trading-off various functions at the design stage (ISO/CD 16951 N287, 2000).

Displays showing high priority information and multifunction integrated visual display screens should be located high on the dash-board and not low in the centre stack console. Only very simple information that is rarely used by the driver should be located in the centre stack console.

5.2.3 Legibility

5.2.3.1 General

To ensure legibility of information the designer needs to consider not only the position of the visual display, but properties such as brightness, contrast, size and resolution. These should be such that the displayed information is clearly legible during daylight and darkness and does not cause visual discomfort or distract the driver when not being directly viewed.

5.2.3.2 Brightness

The brightness (luminance) of the overall display should appear uniform to drivers. While in some conditions the overall uniformity of display luminance may vary, it is best to avoid this within a particular element of the display (eg a sentence).

The brightness of the display should be adaptable to changes in ambient light (eg day or night) to ensure that the display is legible in all ambient light conditions.

5.2.3.3 Contrast

The contrast ratio (see formula below) describes the relation between the luminance of the foreground and background. This should be a minimum of 3:1, whilst a ratio of 5:1 is recommended (HARDIE, 1996). Too high contrast can cause problems of glare, while too low contrast slows down the reading process. The ratio of area average luminance of the display and of the surrounding (luminance balance) should not exceed 10:1 (ISO 15008 integrated, 2000).

$$\text{Contrast} = \frac{L_{foreground} - L_{background}}{L_{background}}$$

$L_{foreground}$ = Luminance of the foreground
$L_{background}$ = Luminance of the background

Reflections and glare visible to the driver on both displays and windscreens reduce legibility, and should be avoided for example through:

- provision of a display brightness control
- appropriate display surface texture and finish
- appropriate colour choice
- appropriate image polarity
- use of a recess or cowl.

Designers should ensure that any reflection and glare reduction, or contrast enhancement techniques of this type, do not cause the display to contravene other relevant standards.

5.2.3.4 Resolution

The resolution of the display should be high enough to show the driver solid images of information via symbol or text. The number of pixels measures a display's resolution. The single pixels of a display tie together to form a contour of a picture (text or symbol). With an increasing number of pixels, the contour of the picture will appear clearer (HARDIE, 1996).

5.2.3.5 Character and spacing

Characters used in a display should be large enough to read in the moving vehicle.

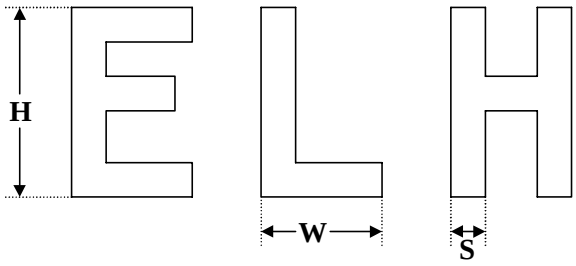

Figure 2: Character height, width and stroke

The minimum required character height (see H in Figure 2) should be a visual angle of 15'. This angle describes the relationship between the viewing distance and character height as shown in Figure 3. The following equation should be used to determine the required character height:

$H = \tan\alpha \times D$

H = character height in mm

α = angle created at the eye by the character height and distance from the display (see Figure 3)

D = distance from the driver's eye to the display in mm.

The minimum requirement of 15' is recommended for static or non-critical information (Mourant, 1976). Since a vehicle is in motion and vibrates, reducing legibility, it is recommended that character height is at least 24' (ISO 15008 integrated, 2000). With a visual angle of 20' at a normal reading distance in a vehicle (700mm) the minimum character height would be 4 mm.

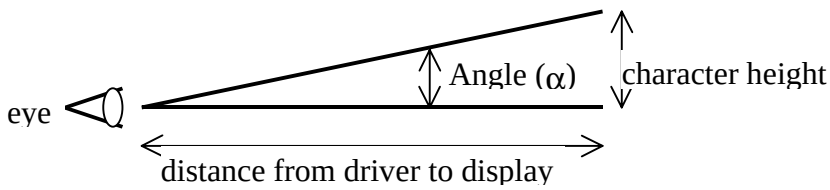

Figure 3: Minutes of arc.

The ratio between the stroke width (see S in Figure 2) and character height should be between 1:12.5 and 1:6.25. The ratio should be lower for more prominent, dynamic and safety critical information. The more critical the information, the wider the character should be (up to a ratio of 1:6.25).

The width of a character (see W in Figure 2) is very dependent on the height of that character. The relation between the width and the height of the character should be between 0.5:1 and 1:1, whilst a ratio between 0.6:1 and 0.8:1 is recommended. A wider symbol should be provided for more prominent, dynamic and safety critical information. The more critical the information, the wider the character should be, up to a ratio of 1:1.

Character spacing refers to the horizontal space between adjacent characters. This is usually expressed in terms of the stroke width of the characters. The space between the characters should be a minimum of one stroke width. Wider spacing should be used for more prominent, dynamic and safety critical information. The more critical the information, the wider the spacing should be; although legibility will be reduced if it becomes excessively large.

5.2.3.6 Font

The type of font used to display text is an important factor in legibility and comprehension.

- The font type should be clear and simple. Sans serif fonts are recommended (eg Arial, Helvetica; not Times).

- No more than two different fonts and two types of emphasis (eg bold or underlining) should be used (HARDIE, 1996).

5.2.3.7 Case

- The use of mixed (or 'sentence') case with a ('standard') combination of lower and upper case letters makes characters and messages more easily recognisable; and should be used for written text rather than using all capitals or lower case.

- However, if resolution is low (eg less than 32 x 32 pixels) and 'descenders' (eg 'p', 'g', 'y', etc) are not possible - the use of upper case only may be considered as a (second best) alternative.

5.2.4 Colours

Colours should be:

- coded such that their meaning is clear and should conform to stereotypical norms (DIN EN 60073, 1997)
- used to make it easier to find the required information under both day and night-time viewing conditions
- chosen so that red/green and blue/yellow combinations are avoided.

Colour should not, however, be used for actual messages, as this would increase the reading time.

The use of too many colours should also be avoided. A maximum of five different easy to distinguish colours is recommended (excluding black and white).

It may be appropriate to have three levels of priority indicated by colour, eg 1) Red – Alarm, 2) Amber – Warning and 3) White – Information/ status.

5.2.5 Symbols and graphics

The use of graphics and symbols should be appropriate to their function and should conform to stereotypical norms. The advantages with symbols compared with text are that they erase language barriers and can be recognised faster and from a greater distance.

The graphics features or symbols should be consistent throughout the IVIS system and should not be too detailed or complex, as this can increase the time taken to identify appropriate information.

- Where possible, the graphics features should be functionally grouped, but not cluttered.
- When unfamiliar symbols are used, a text label of limited text should accompany them, but should otherwise be avoided.
- For ISO 2575 symbol and tell-tales, or similar, a matrix 32 pixels x 32 pixels is the minimum (ISO 9241-3).
- Commonly accepted or standardised symbolic icons should be used (Campbell *et al*., 1998; ISO 4040).
- The comprehension of non-standard and unfamiliar symbols should be tested.

5.2.6 Screen image stability

The screen display should not vibrate or flicker to an extent where information becomes blurred, (the eye is capable of detecting luminance flicker of up to 90Hz in some circumstances). Vibration or flicker are likely to increase reading time and consequently the time required to complete the task and thus will increase visual distraction from the driving task (HARDIE, 1996).

5.2.7 Image blinking

Blinking (or flashing) of any visual image should only be used to attract attention and inform about critical conditions. For attracting attention, a single blink frequency of 2 to 3Hz with a duty cycle of 50% is recommended. If legibility of the displayed information is required, a single blink rate of 1/3 Hz to 1Hz with a duty cycle of 70% is recommended (ISO/DIS 15008). It is inadvisable to use blink rates of 4Hz or greater since these may cause physiological discomfort, including nausea and dizziness. Adjacent blinking areas can also produce motion and metacontrast effects that might be distracting.

5.2.8 Scrolling displays

Scrolling is used when information is too large to fit onto one screen. It usually requires sustained visual and manual interaction, or, in the case of a series of automatic sequentially scrolled displays, numerous sustained glances. Scrolling is therefore not suitable to use within the driving environment.

5.2.9 Head-up displays

Head-up displays (HUD) consist of a virtual image that is optically superimposed on the driver's forward field of view, using either the windshield or a separate optical element.

The safety benefits of HUDs are generally small and in some instances HUDs produce poorer performance (Gish and Staplin, 1995). Therefore the following guidelines should be followed:

- do not present the HUD image in the driver's central field of view as it will mask external objects
- drivers should be able to turn the HUD off
- important HUD information should be coupled with an auditory alert

- while the HUD image must be visible in all potential viewing conditions, luminance contrast requirements for HUDs are a concern because of the dynamic interference with the background road traffic environment
- virtual image distances should be between 2.5 to 4 metres from drivers' eyes
- information should only be displayed temporarily in the HUD. The HUD should not be used to display information continuously
- HUD displays should not be used to present complex information, for example detailed navigation information that cannot be processed quickly, rather, a simple display with very few elements should be used
- use images that conform to the road environment (eg virtual road signs projected by the roadside).

5.2.10 Message

Messages presented while driving should not consist of more than four units of information. Concrete words which have clear meanings should be used whenever possible (McDougall, 2001).

Numerical data should use accepted and understood units; and provide an appropriate level of precision.

Abbreviations should only be used when it is necessary; and should not be used for safety- critical information. Where abbreviations are used, these should be widely known, have clear meaning, be used consistently and conform to national conventions. Where available, internationally and nationally agreed standards related to abbreviations should be used (European Commission HMI TF, 1998).

Safety critical information should be given in a command style. However, the command style should be used infrequently.

High priority messages, such as immediate hazards or vehicle status warnings, should be preceded by an auditory alerting tone.

Messages that convey non-critical information should be given in an informative style.

5.3 AUDITORY INFORMATION

5.3.1 General

Designers should only consider the use of auditory information when this is the most appropriate modality for the type of information being delivered. Auditory information is most suitable when the driver's attention needs to be gained, when the message is short and simple and does not need to be referred to later. Where possible and appropriate, the combination of visual and auditory information presentation should be used.

Ideally the system should enable the last auditory message to be repeated by means of a simple button press, or voice command, as the driver may have been distracted

during the initial presentation of the auditory information, or may have forgotten or not have understood the message.

It should be possible to control whether the auditory information is turned on or off and feedback about the current status of the auditory information should be presented every time the system is turned on.

5.3.2 Volume

It should be possible to hear the auditory output under all driving conditions at a level that will not startle the user. The volume of auditory output should be adjustable over a reasonable range; in most circumstances between 50dB(A) and 90dB(A) is suitable. Higher than 90dB(A) should be avoided.

Sounds containing different frequencies should all be presented at an appropriate volume, usually this can be achieved if the signal exceeds the ambient noise by 15 dB or more (Sorkin, 1987). However, to avoid a startle response, the signal should not exceed ambient noise by more than 25dB (Edworthy, 1994). The signal level is a matter of balancing the listener comfort against message audibility.

5.3.3 Frequency

Auditory information should always lie within the range of human hearing (ie 200 - 8000Hz), but it is recommended in practice that it should lie between 500 and 4000Hz (ISO 15006-1). It needs to be designed, however, such that a driver is not prevented from hearing interior or exterior warnings.

5.3.4 Auditory information presentation

When multiple sounds are used within complex systems, the sounds should be designed as an integrated set. By doing so, the audibility of the signals with one another and background noise can be optimised (Robinson, 2001).

5.3.5 Speech

Designers should ensure that when using speech to convey messages:

- the system should give immediate feedback (ie within <250 ms) to the driver
- messages should be short and simple and should not need to be referred to later
- if messages cannot be presented in a short sentence, the most important information should be presented at the beginning of the message, and could be repeated again at the end
- the vocabulary used should be familiar to drivers and should avoid using similar sounding words or phrases
- messages that require an urgent action should be a single word or a short sentence and should be understood immediately
- the system should be able to cope with background noise and should not be influenced by it, a signal to noise ratio (SNR) of around 5dB(A) should be sufficient to ensure audibility (ISO/CD 15006 1996)

- where messages contain instructions, they should be presented in a logical order for example rather than ‘turn left in half a mile, the message should be ‘in half a mile, turn left’.

6 DRIVER-SYSTEM INTERFACE: DIALOGUE MANAGEMENT

6.1 GENERAL INFORMATION PRESENTATION

In general there are four types of information that can be conveyed to the driver (Galer, 1983):

- warnings
- advisory information
- diagnostic information
- entertainment.

Warnings provide information that is of vital importance to the safe operation of the vehicle and in-vehicle systems. Advisory information is also useful for the safe operation of the vehicle and in-vehicle systems, but this tends to be vehicle status information that is less time critical and severe (eg telltales). Diagnostic information explains the condition of the vehicle for maintenance purposes. Some vehicle information can also be provided through the entertainment system (eg traffic bulletins via the audio system).

System design should ensure that information presented to the driver should be correct, consistent and compatible with the road network. The quantity of information presented to the driver should not be excessive.

When it is not possible for the driver to comply with the IVIS instructions, the driver should be clear about how the system will respond. Ideally the system should recognise the failure to respond and compensate for the non-compliance by offering a confirmation message and updated advice.

6.2 VISUAL INFORMATION PRESENTATION

Designers should ensure that when the in-vehicle system consists of different functions (eg route guidance, entertainment and e-mail), these should be fully integrated. Preferably the system should have one interface, and features such as colours, formats, and menus should be consistent throughout the different functions. This is a particularly important consideration if drivers have access to information from 3rd party providers (eg through the Web portal).

A display should be organised in such a way that drivers can direct their attention to the relevant information and find it easy to understand and respond to that information. The display should therefore be simple in overall density, local density, and grouping:

- overall density: the percentage of the total number of characters or symbols that could occur in the display space. High information density may cause overload and increase errors and difficulties in finding appropriate information
- local density: the amount of space that is filled around a symbol/item. Blank space provides structure in a display

- grouping: considers how close items are and how likely it is that they are perceived as groups.

On first sight of a visual display, areas of high contrast attract the attention. Contrast between different parts of the display should therefore be created where appropriate to aid the direction of attention, and understanding of the information being presented (McDougall, 2001).

6.3 CHOICE OF DISPLAY MODALITY

Designers should avoid presenting complex visual information to the driver of a moving vehicle if possible. A visual display should only be used if this is more compatible with the function than other modalities, such as speech.

The driver should be able to assimilate visual information with a few glances, which are brief enough not to adversely affect driving. A brief glance refers to glance duration of around 1 second representing the normal case and a maximum single glance of 1.5 seconds (Wierwille, 1993).

If the system provides non-safety related dynamic visual information (for example navigation, parking or traffic information), it should be possible to be switched into a mode where that information is not provided to the driver of a moving vehicle.

Non-driving related information (eg TV or video) should be disabled or presented in such a way that the driver cannot see it while the vehicle is in motion (DD235, 1996).

6.4 INDIVIDUAL PREFERENCES

Designers should recognise the advantages of systems that allow drivers to tailor the presentation of information to their own preferences and driving requirements, especially for information requiring direct responses. Although drivers should not be able to do this whilst driving and available options should be within reason. The setting of personal preferences should, however, be restricted within safe limits in order to prevent the inadvertent loss of information.

When maps are displayed within the vehicle, the system should distinguish clearly between system modes. For example it should be clear when the vehicle is in the middle of the display (re-centred map mode), or when the vehicle moves relative to the stationary map (normal display mode).

6.5 MENU FACILITIES

It should be easy to navigate through the system menus. It should be simple to return to the start or escape from a dead end. These options should be consistent throughout the system.

There should be an appropriately small number of menus, submenus and final options. The number of choices per menu should be limited to three or four. Frequently used functions should have dedicated single function control keys rather than be located within the system menu structure.

For interactions involving more than one screen, the driver should not have to remember information from one screen to the next.

6.6 TEMPORAL INFORMATION

The system's response to driver input should be timely (see section 5.1.8) and clearly perceptible. If a response takes longer than 250ms, the system should inform the driver that it has recognised the input and is busy preparing a response (European Commission, 1998).

Visual information should be presented for a sufficient length of time that allows the driver to observe it in their own time when other task demands are low, or remains displayed / re-presentable, until the driver acknowledges that he has observed it, or the message becomes out of date.

The IVIS should be free from 'machine-pacing'. The driver should be able to control the pace of the interaction with the system. It should be possible to interrupt a sequence of interactions and resume again at the point of interruption or at another logical point.

When new information arrives that is directly relevant to the current driving situation (eg a coming turn), a suitable indication should be given in advance of a driver decision. Two or three messages should be used sequentially including the time and/or distance to the event.

6.7 CONSISTENCY

Information presented to drivers should be consistent and compatible with the road network. Consistency is also how well a system matches a driver's expectations. IVIS handling, appearance and behaviour should conform to the driver's expectations. The driver's expectations can be a function of their experience with the system or similar systems and commonly accepted conventions. Expectations will also vary with individual differences such as knowledge, culture and gender.

Message terminology and icons should be consistent between displays. Colours should be consistent between displays of similar function. Controls should behave consistently. Avoid changing modes where user interaction requires different actions than in other states (eg adaptive multifunction buttons). Organise data fields to match user expectations.

Inconsistent systems, ie those that do not match driver expectations, will be more difficult to use and take more time to learn. Inconsistent systems will cause more errors. The severity of this problem will depend on the system function.

6.8 SIMPLICITY AND QUANTITY

Simplicity refers to the ease with which IVIS tasks are performed and information understood. IVIS systems should not allow or demand any complex tasks. The amount of information on display should therefore be restricted. Complex IVIS tasks

will distract the drivers' attention from the primary task. This will reduce driving performance and compromise road safety.

Visually displayed information should be such that the driver can assimilate it with a few glances that are brief enough not to adversely affect driving. If the information cannot be acquired in a few brief glances driver workload and visual distraction may increase. Driving is adversely affected when the driver is distracted or overloaded which, may result in situations where their actions, or lack of actions, increase the risk of a crash.

In order to maintain simplicity the following principles should be adopted (European Commission, 1998; BSI, 1996):

- use single words or simple and familiar icons where possible
- dialogue should not contain information that is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility. Eliminate unnecessary information
- maintain display inertia - make sure the screen changes little from one screen to the next within a functional task situation, unless new information is being presented
- use concise, unambiguous wording for instructions and messages
- use a balanced screen layout with plenty of 'white space' around text blocks (at least 50% 'white' space for text screens)
- keep backgrounds simple and muted
- group information logically
- structure the information rather than just presenting a narrative format. Organise information into a small number of "chunks"
- functionality should be clear. Hidden functions tend to stay that way
- allow users to tailor frequent actions.

6.9 SYSTEM DIALOGUE IN A MOVING VEHICLE

System dialogue refers to the communication and interaction between the driver and IVIS. Only IVIS tasks that do not directly or indirectly increase the risk of collision or injury to vehicle occupants or other road users may be suitable for use while driving.

Complex information and control actions should not be designed for use in a moving vehicle because they can be too distracting for the drivers. Guidelines to be followed include:

- any IVIS functions that are accessible, but not designed for use when the vehicle is in motion, must be clearly indicated as being restricted
- long sequences of interactions with the system should not be required. Drivers should be allowed to interrupt the sequence at any time without consequence
- there should be a balance between the breadth and height of menus. The number of choices should be limited to three or four options to minimise the complexity and interaction time
- an 'off' or 'mute' option should be available

- system response (eg feedback, confirmation) to driver input should be timely (< 250ms) and clearly perceptible
- avoid unnecessary attention-grabbing techniques (eg Boeing's Dark and Silent cockpit metaphor: 'Do not blink or beep unless absolutely necessary')
- prioritise information
- no low priority system initiated information
- drivers should be able to initiate and control the pace of interaction with the system; no time-critical responses should be required when providing input to the system
- keep the user informed about system status
- do not display information when the driver is busy, although this guideline is for more advanced “intelligent” systems, eg GIDS (Michon, 1993).

If an IVIS task is too distracting, it can either be re-designed or removed. Complex IVIS functions can be locked out to prevent in-transit use. These functions should be accessible only when the vehicle is stationary.

7 OTHER SAFETY RELATED ISSUES

7.1 GENERAL

There are a number of general safety issues that need to be taken into account in the design of IVIS. The main concerns are driver overload and attentional demands that can distract the driver from the primary driving task. Systems can be a hazard to safety if they are not designed to be compatible with driving.

The use of in-vehicle systems must not directly or indirectly increase the risk of collision or injury to vehicle occupants *or other road users*. Drivers must be able to use in-vehicle systems easily, effectively and satisfactorily; and in a way that is compatible with and suitable for driving.

In order to be safe and compatible with driving, IVIS must have good usability and not be distracting. Some IVIS design guidelines for optimising ease of use and avoiding distraction are presented in this section.

7.2 DRIVER DISTRACTION

7.2.1 Definitions

In order to understand how a driver might be distracted from a task, it is first necessary to introduce the concept of 'attention' (to a task). Attention has been defined as the selectivity of cognitive processing that involves focussing or concentrating on one area of thought in order to deal with it effectively (Eysenck, 1994). When drivers attempt to attend to more than one stimulus at a time, their attention becomes divided; and if a secondary task is difficult or demanding they may become distracted from the primary task.

The literature provides a number of definitions for distraction. Janssen (2000) used distraction to refer to the capture of the driver's attention by information that is irrelevant to the driving situation to a degree where insufficient attention is left for the primary task. Ranney *et al* (2000) defined driver distraction as any activity that takes a driver's attention away from the task of driving. Some authors use driver distraction to mean the allocation of attention to the system displays or controls that has a negative effect on driving performance.

7.2.2 Driving

The primary task is to monitor and control the vehicle's lateral and longitudinal position along a safe path. At the simplest level this involves controlling steering and speed, tasks that with time and experience become almost automatic requiring little cognitive effort. At more complex levels additional manoeuvres will be required, for example overtaking, and manoeuvring appropriately at junctions and roundabouts. These tasks demand greater cognitive effort and the introduction of additional information for example from a route guidance system while undertaking these tasks will create an unwanted distraction (Allen *et al*, 1971; Tijerina *et al*, 2000).
A distraction can be visual, auditory, cognitive or biomechanical (Ranney *et al*, 2000). Something that takes driver's visual attention away from the road or changes their

glance behaviour is a visual distraction (eg reading a map). Listening to music while driving could be an auditory distraction. An activity that demands thought can be a cognitive distraction if it takes the driver's mind off the road traffic environment (eg engaging in a call on a hands free mobile phone). Something that requires the driver to lean forward, take their hands off the wheel or stretch to operate can be a biomechanical distraction (eg adjusting the volume on an entertainment system). These biomechanical distractions can force drivers off their normal sight lines and impair their control of the vehicle. Many distracting activities that drivers engage in can involve more than one of these four components. For example, tuning the radio or dialling a mobile phone may involve all four components of distraction.

Distracted drivers are more dangerous because they may be unable to adequately monitor and control the vehicle's safe path while performing an IVIS task. It is the coincidence of driver inattention and the occurrence of unanticipated events (eg curve in the road, pedestrians crossing) that causes distraction-related crashes (Ranney *et al*, 2000).

The driver may try to regulate the consequences of distraction by reducing the attentional demands of the driving task in terms of lowering the amount of effort required to perform it and its level of difficulty for example by slowing down. However, there will be times when this type of regulatory behaviour is not possible, for example when making judgements about time-gaps at intersections.

The system should be designed in such a way that the allocation of driver attention to the system displays or controls remains compatible with the attention demands of the driving situation.

7.3 SYSTEM FAULT AND INPUT ERROR WARNINGS

If the IVIS is inoperative at the start of a drive (when activated by the driver), or fails during it, the driver needs to be made aware of the situation.

Drivers will make mistakes while using IVIS, so the systems must be tolerant of user input errors. It must be possible to easily recover from errors and the consequence of potential errors must be minimised. Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution. Some other guidelines for system faults and warnings are (European Commission, 1998 and ISO 15005 - currently being approved):

- the driver should have immediate and clear feedback for input errors
- use reminders, or warnings only as appropriate
- provide user-centred wording in messages
- avoid ambiguous messages, use plain language and indicate the precise problem
- avoid using threatening or alarming messages unless appropriate
- use specific, constructive words in error messages (eg avoid general messages such as 'invalid entry' and use specifics such as 'please enter your name')
- make the system 'take the blame' for errors (eg systems should respond 'unrecognised command' rather than 'illegal command')

- avoid automatic switching to other modes when desired functions become inaccessible
- make user actions easily reversible, allow 'undo' commands and other escape routes from operations.

7.4 BEHAVIOURAL ADAPTATAION

Another safety concern for IVIS is behavioural adaptation; as drivers become more familiar and experienced with a particular system they may adapt / modify the way in which they interact with it and the information it provides.

The Organisation for Economic Co-operation and Development (OECD, 1990), refers to behavioural adaptation as those "…behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change". Designers should consider that potential safety benefits and behavioural impact of new in-vehicle systems may be reduced by behavioural adaptation; for example, drivers may consider using route guidance systems to help them find their way in fog when without the IVIS they would not travel.

In this context the more advanced and sophisticated the system – and the more useful information it offers the driver – the more such adaptation and reliance will become a factor. The only effective way of assessing – or evaluating – such concerns are by instigating long-term trials.

7.5 ACCURACY OF INFORMATION

Designers need to recognise that presenting drivers with inaccurate – or untimely – information is likely to have serious safety implications in some circumstances. In general it is advisable not to present inaccurate information and to ensure that a system will fail-safe.

Systems need to take into account the accuracy of the information provided by external sources, for example GPS for vehicle positioning, and allow for possible inaccuracies in this information.

As well as being accurate information also needs to be unambiguous and not open to misinterpretation by the driver.

7.6 ROUTING AND SAFETY

System design may need to take account of a changing road network. The IVIS needs to be able to deal with:

- temporary diversions (eg caused by road works or accidents)
- minor changes to network (eg new one-way systems)
- upgraded roads (eg from single to dual carriageway).

If drivers are required to leave the suggested route the system needs to recognise this and ‘recalculate’ the route guidance provided.

If ‘maps’ are used they will need to be updated on a regular basis. Designers should build in provision for updates and notify the user of how this will be done.

8 THE LEGAL SITUATION (FOR UNITED KINGDOM)

These guidelines deal with the current legal situation with regard to IVIS, that apply in the United Kingdom, although similar provisions do apply throughout Europe.

When examining the legal situation concerning any new in-vehicle device, it is necessary to consider each of the following:

- Responsibilities.
- Traffic law.
- Licences and contracts.
- Type approval.
- Tort liability.
- Consumer protection liability.
- Health and Safety at Work Act.

8.1 RESPONSIBILITIES

Each person, or organisation, in the IVIS supply chain has responsibilities to ensure that systems do not compromise either the safety of the users themselves - or of other road users. Importantly they may be required to prove that they properly fulfilled their legal responsibilities in a court of law in the event of some improper functioning, confusing information or breakdown resulting in an injury or accident taking place.

This applies not only to those supplying the system – or possibly installing it – but also employers expecting their staff to use the system and vehicle hire companies renting or leasing vehicles who should also accept responsibility for maintaining or repairing any system fitted in their vehicle – or at least warning drivers that a fitted system is not functioning properly. While it can be argued that drivers themselves bear the ultimate responsibility for their own (and other road users) safety, it can also be debated whether they were given sufficient verbal guidance or advice (or written instructions) about safety aspects of the IVIS. Ideally a copy of the manufacturer's user instructions should be provided (and remain) in every vehicle.

The provision and use of in-vehicle information systems needs to comply with a variety of complex legal issues that deal with human machine interaction, driver behaviour, responsibility and safety. Systems must comply with the rules that allow vehicles and drivers to be part of public road traffic and the rules of traffic law. Also the civil and penal liability of the driver/keeper of a vehicle and the rules on the product liability of manufacturers and suppliers are relevant.

Drivers should ensure that they have access to manufacturers' instructions and take adequate steps to be aware of their content before driving on the road. They should not use a system until they are able to do so safely and may need to allow themselves a period of training or familiarisation.

8.2 TRAFFIC LAW

The construction and use of vehicles on public roads is governed mainly by Part II of the Road Traffic Act 1988. Under this, the "Construction and Use" regulations set out

in detail a number of requirements on aspects of vehicles such as steering, vision, instruments and equipment (eg speedometers and audible warnings).

The Road Traffic Act also describes driver responsibility and offences related to dangerous, careless and inconsiderate driving. Drivers are expected to be responsible for the proper control of their vehicle. That is not to say that they are solely and always responsible for everything as some aspects of the vehicle's performance are outside of their control eg Advanced Braking Systems.

Drivers are therefore expected to be in control of the operation of an information/communication system. This philosophy is re-enforced by the Highway Code, Paragraph 128 which states:

> "There is a danger of driver distraction being caused by in-vehicle systems such as route guidance and navigation systems, congestion warning systems, PCs, multi-media, etc. Do not operate, adjust or view such a system if it will distract your attention while you are driving; you **MUST** exercise proper control of your vehicle at all times. If necessary find a safe place to stop first".

The penultimate sentence, as indicated by the "**MUST**" is a reference to the 1988 Road Traffic Act (Sections 8.2 and 8.3). According to the Road Traffic Act, a failure on the part of a person to observe any provision of the Highway Code shall not of itself render that person liable to criminal proceedings, but such a failure may in any proceedings (whether civil or criminal) tend to establish liability. Thus, the Highway Code does not have the power of law but it quotes from other laws and has the status of a "Code of Practice" such that a court is likely to expect drivers to follow its provisions.

8.3 LICENCES AND CONTRACTS

The operation of in-vehicle devices may be subject to the granting of licences. Road Traffic (Driver Licensing and Information System) Act 1989 concerns licences specifically for systems requiring instillation of equipment on public highways and/or systems providing turn-by-turn route guidance in accordance of prevailing traffic and road network conditions. Other licences that may be relevant, depending on the exact nature of the system include:

- Radio-Telecommunications licence.
- Infrastructure/Planning consents.
- Service licences (eg for digital information transmission).
- Copyright licences for software or mapping.

Manufacturers should, for example, comply with the Statement of Principles on human machine interface (HMI) for in-vehicle information and communication systems (European Commission, 2000/53/EC).

A contract is an agreement between parties, enforceable by law that sets out obligations, duties and liabilities. However, under English law, a person cannot restrict his liability for death or personal injury caused by his negligence or intent.

The exact nature of contracts between component manufacturers, system manufacturers, software providers and vehicle integrators will have a bearing on how liability is apportioned for the development and use of all in-vehicle information systems.

8.4 TYPE APPROVAL

The Type Approval process serves the purpose of ensuring that agreed and acceptable levels of performance in general, and safety in particular, are provided in new road vehicles. This process gives the consumer some level of protection and enables "free trade" between countries via international harmonisation of legal requirements.

Standards should not be confused with Type Approval. Standards are voluntary agreements that can become law if they are quoted in an EC Directive or Type Approval specification. Standards may also be held up as representing the "state-of-the-art" although as they are often the outcome of negotiations, they may not actually reflect this.

Designing a product to meet government or industry standards does not guarantee that it will not be found defective. Traditionally courts have taken the position that all standards provide, at best, lower limits for product acceptability. Codes of practice (Statements of principle etc.) are likely to be viewed in a similar way if derived through negotiation.

Across Europe two systems of Type Approval are currently in place. One is based around EC Directives and provides for the approval of whole vehicles, vehicle systems and separate components. The other is based around ECE (United Nations) Regulations and provides for approval of vehicle systems and separate components, but not whole vehicles. The importance of Type Approval will depend on the IVIS being designed, for example introducing in-vehicle display screens may impact on the following Directives:

- Field of view (77/649/EEC).
- EMC (95/54/EC).
- Interior fittings (74/60/EEC).
- Controls & Indicators (78/316/EEC).
- EMC (95/54/EEC).

Automotive regulations between the EC and ECE have close parallels and there is mutual recognition between many of them.

Whole vehicle type approvals are valid for the life of the vehicle. Replacement parts, in theory, should be identical, but in the UK, parts that the manufacturer claims are of the appropriate standard are considered acceptable. For after-market installation in the UK, it has generally been assumed that equipment such as information screens can be regarded as "de minimus" additions to a vehicle that would not impact on existing approvals. Thus, after-market information and communication systems are not required to comply with Directives such as "interior fittings" requirements that specify minimum radii (avoiding sharp edges) and impact-friendly design. However, it appears sensible from the liability perspective for after-market manufacturers to be

knowledgeable about the requirements for new vehicles and follow the same requirements.

8.5 TORT LIABILITY

Although the liability of parties to an agreement is governed by the contracts between them, they may also be liable in tort, particularly to third parties such as drivers with whom they have no contract.

Tort liability requires it to be established that the defendant (for example, a manufacturer or software provider) specifically did something to cause harm or, more likely, did not do something to prevent harm (negligence). In order to establish liability in negligence the claimant must first show the existence of a "duty of care" and then that a breach of that duty took place.

There could, for example, be negligence in the design/manufacture of an in-vehicle system or in the fitting of it within the vehicle. There could be negligence in the testing of a system; thus assessment data should be retained in the event of product liability claims, or the granting of a licence for it. The functionality of many in-vehicle information systems is likely to extend to a duty of care on information service providers and may provide wider scope for claims of negligence.

8.6 CONSUMER PROTECTION

Section 2 of the 1987 Consumer Protection Act introduces "strict liability" in respect of defective products.

According to Section 3 of the Consumer Protection Act, a product is defective when it does not provide the safety that a person is entitled to expect, taking all circumstances into account. These circumstances include:

- its presentation (advertising, user manual, etc)
- the time when the product was put on the market; hence, the "state-of-the-art" defence
- the use which can be reasonably expected; which includes foreseeable misuse.

Products must be designed for reasonably foreseeable use, not just intended use. This requires that the range of actual use is considered and this includes misuse. Specific examples of misuse of driver information systems might include:

- using excessively long glances at the information screen
- using a function (which is accessible while driving) despite the supplier's instruction not to do so
- placing so much trust in the system's directions that mandatory road signs are ignored
- using digital map information that is out of date.

In this regard, attention has also to be given to the second-hand vehicle market to understand how second owners of products use them including, for example, when digital maps become increasingly out of date.

8.7 HEALTH AND SAFETY

The Health and Safety at Work Act (1974) describes the general duties of an employer for the welfare of his employees. Although not directly applicable to designers or manufacturers, it is worth noting that the Act is becoming more relevant to the in-vehicle environment when it is used as a workplace. If this is the case, any employer requiring or expecting their staff to use vehicle based information systems should ensure that the safe operation of the vehicle is not compromised and that the driver or other road users are not put at risk.

Designers should also recognise that the Act may result in a requirement that employers ensure that drivers who are expected to use an IVIS as part of their work are provided with adequate training with the system.

8.8 SUMMARY OF IMPLICATIONS FOR MANUFACTURERS

The driver is responsible for safe control of the vehicle and this includes appropriate use of in-vehicle information systems. However, the driver is also entitled to protection from defective products that do not provide the level of safety that the driver expects in use.

Manufacturers may protect themselves to some extent from product liability claims by:

- designing for reasonably foreseeable misuse
- designing in fail-safe modes
- marketing the product accurately
- controlling maintenance and repair operations
- designing safe systems.

This means that producers of IVIS may be required to carry out extensive testing to check system reliability and check on driver responses to possible system failure or error. Importantly, it will be necessary to provide the end user with pertinent advice about how the system should – and should not – be used.

Another aspect of product liability is the ‘development risk defence’ provided in some national laws in accordance with the EEC Directive. This defence is based on the argument that applying the state of science and art at the time of marketing of the product meant that any defect could not be detected.

Any producer would be advised to both seek professional guidance and comply as fully as possible with any existing Code of Practice provided to assist with development and testing. This is likely to help demonstrate in a court of law that he has exercised his duty of care - although such compliance will not be a guarantee that the duty has been discharged.

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11 ABBREVIATIONS AND GLOSSARY OF TERMS

ABBREVIATIONS

ADAS	Advanced Driver Assistance System
BSi	British Standards Institution
DIS	Draft International Standard
HMI	Human Machine Interface
ISO	International Organisation for Standardisation
IVIS	In-Vehicle Information System
OECD	Organisation for Economic Co-operation and Development
SAE	Society of Automotive Engineers
SNR	Signal-to-Noise Ratio

GLOSSARY

Ambient Light — Surrounding light environment.

Ambient Noise — Surrounding noise environment.

Brightness — The perceived light from a display (SI units of cd/m^2). It is the sum of all light falling on a display and coming from display.

Contrast ratio — Describes the relation between the luminance of the foreground and luminance of the background.

Convention — Established customary practice.

Dialogue — Related set of successive inputs and outputs involving the IVIS and the driver.

Driver controls — These include: accelerator, brake, clutch (if fitted), steering wheel, gear changer, parking brake, horn, light switches, turn indicators, washers and wipers, hazard lights, de-mist controls.

Driver displays — These include: speedometer, all warning lights, mandatory control labels and mandatory tell-tales.

Feedback — Response from the IVIS giving information to the user about an input action taken, further action that is required, or a change in system state.

Foreseeable Misuse — Use of the IVIS in a way that is not intended, but which the suppliers might be expected to have anticipated.

Free standing Equipment	Equipment that is not securely mounted or installed within the vehicle. It may require hand held operation, for example a remote control device or a mobile phone.
Function	Operation or activity carried out by the IVIS that is executed on reception of incoming information, and transforms this into an information output.
Glare	Distracting (and potentially disabling) effect of bright light in an otherwise relatively dark scene that interferes with visual attention and selection.

Note that for the in-vehicle context, this can occur in a number of ways:
a) External light (usually sunlight) falls on the visual display reducing display contrast and makes the information on the screen more difficult to see from the driver's normal viewing position.

b) The display is itself too bright and causes distraction from the road scene and other in-vehicle displays and controls. This is most likely to be apparent to the driver in low ambient light conditions.

Graphics	Symbolic drawing or illustration used to present visual information, without the use of text or numbers.
IVIS input controls	All elements of the systems interface through which the driver provides control inputs. These include turn-knobs, push-buttons, touch-screens, joysticks, pedals, and microphones.
Luminance	The light emitted from a display (SI units of cd/m^2).
Machine Pacing	This occurs when the speed at which the user must interact with the system is determined by the system rather than by the user.
Manufacturer	The person or organisation responsible for system construction. The term includes the designer, component suppliers and system integrator; plus system suppliers who, by putting a name, trade mark or other distinguishing feature on a product presents themselves as its producer. The responsible organisation will typically be the vehicle manufacturer or the system supplier.
Misuse	The use of IVIS functions (intended by the supplier for use while driving) that are used by the driver in a manner or way that is not intended, and may lead to negative consequences.

Primary driving task	The activities that a driver has to undertake while driving, navigating, manoeuvring and handling a vehicle including steering, braking and accelerating.
Reflection	Reflection is the generation of a secondary image of an object as a result of light from the object bouncing off intermediate surfaces

Note that this is relevant for IVIS in a number of ways:

- Light from a light emitting display travels to another surface (or via several surfaces) producing a secondary image of the display screen for example, on the windscreen. This is most likely to be perceived by the driver when there is high contrast between the secondary image and its background, such as against the windscreen during darkness.

- Light from an external source (eg the sun, streetlights, or other bright objects) is reflected by the display surface into the driver's eyes (see also Glare above).

Supplier	The organisation(s) responsible for design, and production of the system, which designate the envelope of use for the system and provide related documentation.
Usability	Ease with which the IVIS can be used.
Workload	Physical and or cognitive demands made on an individual at any given moment.

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